Supply Chain Management Planning for a Project Using the Fuzzy Logic and Crashing Program Method

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***Abstract*— Project management is a strategy performed in project planning and scheduling. Implementation of project management helps estimating time and cost required to run the project, thus cost losses due to possible delays in the project could be minimized. Project scheduling as part of planning activities, can provide information about project timeline, plans and progress. Project time management can be arranged using Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT). Implementation of Crashing Program Method is one alternative to accelerate project completion by adding project cost. To overcome the uncertainty of project time and cost, Fuzzy Logic is used in the calculation. From the results of Fuzzy Logic calculation, we can estimate the time and cost needed to carry out the project with minimum cost losses due to possible delays. The calculation using Fuzzy Logic on CPM and PERT in project scheduling of house renovation in Bandung results longer project timeline but higher probability of project completion, meanwhile the calculation using Crashing Program Method results a faster project completion and lower incremental cost.**

***Keywords*—** *Project Management, CPM, PERT, Crashing Program, Fuzzy Logic*

1. Introduction

Planning on a project not only requires reliable human resources, but also good project management [1]. Good project management will create a more detailed and efficient stage of project implementation, thus it can provide project schedule and project progress information and costs through structured planning [2]. Project management is the application of knowledge, expertise, equipment and techniques to project activities that suit the needs of the project [3].

A project needs to strive to improve quality results through actions through structured planning, so that it is more optimal in using resources [4]. The initial success of a project must begin with systematic planning and structuring [5]. One way to make the project run smoothly and according to plan, is by implementing project management. Project management is a strategy that needs to be done so that project completion is efficient and effective. In the implementation of projects in general, many face problems both related to time and cost so that structured planning is needed [6]. In project planning the optimized time and cost are very important to know. The thing to do in optimizing time and costs is to create a network of projects, look for critical activities and calculate the duration of the project. CPM and PERT methods are aids in project management related to the planning and control of a project.

Research relating to project management has been widely carried out by previous researchers. For example research conducted by Demirkesen and Ozorhon [7], analyzes project management performance based on the influence of various components of integration management. The next step is to calculate the relationship between the components of integration management. Data obtained from questionnaires that have been compiled and given to respondents. The results obtained that the project management performance is strongly influenced by the integration management component. Research conducted in different years by Bjorvatn and Wald [8], extends the complexity of the project. The concept of team-level absorption was added to the analysis process as a mediator and project management success. The structural equation modeling method is used in the analysis process. It was found that team-level absorption had a direct and positive impact on the success of project management. In another study conducted by Åsgård and Jørgensen [9], analyzing the factors that occur as a result of the lack of recognition of the initial stages of project management. Factors analyzed were health and safety at the construction stage. From the results of the study indicate factors that affect health and

safety in the initial phase of the construction project in the form of a lack of competence, lack of consequences and lack of priorities. In the study of Ekemen and Şeşen [10], analysing the ability of project leaders to interpret insights into the dimensions of project management behaviour. The structural equation model is used in the analysis process. The results showed that the integration of knowledge in project management had a positive and significant impact. Research related to project management can be seen at [11] - [14].

Based on the description above, the researcher aims to carry out project management by optimizing time and cost. The object and target of this research is the house renovation project in Bandung. In this study it is interesting to study because of the fact that the scope of conditions is very limited, an obstacle in project management. In addition to overcome the uncertainty of time scheduling and project costs in the calculation of Fuzzy Logic is used. Thus the results of this study obtained optimal cost and time planning in the completion of renovation of houses in Bandung.

2. Research Model

2.1 Project management

Project management is the process of planning, organizing, leading, and controlling the activities of organizational members and other resources so that they can achieve the specified organizational goals [3]. The purpose of project management is to be able to manage management functions up to the requirements that have been established and have been obtained to obtain resources that are as efficient and effective as possible [3]. CPM and PERT methods are aids in project management related to planning and controlling a project.

2.2 CPM and PERT methods

The method used in project management to obtain optimum results related to planning and controlling a project is to use CPM and PERT. The main difference between CPM and PERT is that CPM includes the concept of costs in the planning process while PERT is assumed that the cost varies according to the length of time of all activities contained in the project.

a. *Critical Path Method (CPM)*
CPM is a critical path method that uses a network with a balance of time and cost [15]. The CPM technique is carried out by arranging a network that is identified in terms of activities and using simple time estimates for each activity that shows the implementation period. Forward calculations and backward calculations can be started by determining:

- Advanced calculation can be started by determining ES (Earliest Start) and EF (Earliest Finish) :
$$EF_{(i,j)} = ES_{(i,j)} + t_{(i,j)}$$
$$ES_{(j)} = \max(EF_{(1,j)}, EF_{(2,j)}, \ldots, EF_{(n-j)})$$
- Countdown can be started by determining LS (Latest Start) and LF (Latest Finish) :
$$LF_{(i,j)} = LS_{(i,j)} + t_{(i,j)}$$
$$LS_{(i)} = \min(LF_{(i,1)}, LF_{(i,2)}, \ldots, LF_{(i,n)})$$
- $Slack\ /\ Total\ float\ (TF)$ calculated by finding the difference between the time of the slowest start of an activity and the time for the start of the activity, or by finding the difference between the time of the slowest completion of an activity and the time when the completion of the activity is the fastest [1], where
$$TF = LS - ES$$
$$TF = LF - EF$$

b. *PERT Method (Program Evaluation and Review Technique).*
PERT is used in scheduling, managing and coordinating the activities of activities in a project. In the PERT Method there are 3 estimated times namely, optimistic time or the fastest time the work is completed (t_o), the most likely time the work is completed or most likely (t_m) and the pessimistic time or the longest time the work is completed (t_p). After determining the three estimated time periods, then it can determine the expected activity time (Expected Timed), namely: [16]

$$Expected\ Time = \frac{optimistic + (4\ x\ most\ likely) + pesimistic}{6}$$

In determining the estimated time of the project is calculated using probability calculations, namely P ($Z = \frac{(x-\mu)}{s}$)

Where $s^2 = \left(\frac{t_m - t_o}{6}\right)^2$ so $s = \sqrt{s^2}$

2.3 Program Crasing Method

Crashing Program is a method to shorten project duration by reducing the time from one or more important project activities to less than the normal time of activity. In the crashing program there are several components, namely Normal Time (NT), Time of crash (CT), Normal Cost (NC), Cost of crash (CC), [17]. The difference between normal

time and crash, that is Δt = NT-CT, and the difference between normal and crash costs, is ΔC = CC-NC. The cost of acceleration per unit time (slope) is a direct cost to complete the activity at the fastest conditions as indicated by the equation

$r = \Delta C / \Delta t$

2.4 Fuzzy Logic

Fuzzy logic is a rule-based decision making process that aims to solve problems, where the system is difficult to model or ambiguous. In Logic there is a membership function. The membership function is a curve that can show the mapping of data input points into the membership value. One method that can be used to obtain membership values is through a function approach, which is a representation of a triangular curve. A triangle curve is a combination of two linear lines. The representation of the triangle curve can be seen in the following equation, [18]:

Membership Function:

$$y[x] = \begin{cases} 0 & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & b \leq x \leq c \\ 0 & x \geq c \end{cases}$$

3. Results and Discussion

3.1 Research Objects

The object in this study uses secondary data obtained from the RAB of Bandung Housing renovation project. The steps of the analysis in this study are:

a) Retrieval of data as research objects
b) Determine the network and estimated time of project completion using the CPM Method
c) Determine the probability of the project using the PERT Method
d) Determine the acceleration of time and the addition of project costs using the Crashing Program Method
e) Determine the CPM, PERT and Crashing Program after using Fuzzy logic.

3.2 Data Analysis

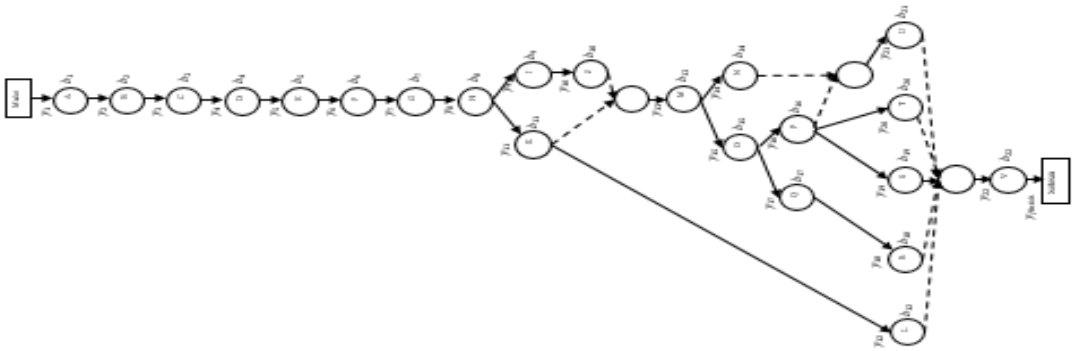
The data analysis sequence begins by discussing the project scheduling "Renovation of Houses in Bandung Housing". The following data are used as research objects.

Table 1 Research Data

Activity	Job Description	Preceding Activity	Time (Day)	Cost (IDR)
A	Initial Preparation	-	1	261,360
B	Demo	A	14	5,707,250
C	Soil Excavation	B	3	1,519,200
D	Foundation	C	27	10,772,085
E	Concrete 1	D	13	5,751,338
F	Concrete 2	E	51	14,496,900
G	Concrete 3	F	8	5,433,513
H	Couple	G	15	10,454,750
I	Hood & Roof	H	31	9,390,571
J	Electrical Installation 1	I	5	3,005,760
K	Water Installation	H	5	1,006,847
L	Page	K	14	3,121,292
M	Plastering	J,K	15	29,316,571
N	Aluminium	M	6	2,101,066
O	Ceiling	M	9	10,864,520
P	Floor & Wall Coverings	O	8	8,025,755
Q	Electrical Installation 1	O	4	1,908,000
R	Painting	Q	4	5,477,920
S	Sanitary ware	P	8	1,801,144
T	Iron Stairs & Fences	P	4	5,170,000
U	Door	N,P	4	1,905,000
V	Location Cleaning	L,R,S,T,U	1	1,051,320

Source: Budgeting of a Home Renovation Project Bandung Housing)

Based on Table 1, the following networks are obtained:



Picture 1. Home Renovation Project Network

3.3 Application of CPM, PERT and Crashing Program methods

In this study the CPM and PERT methods are used to analyze data to determine the possibility that the project can be completed according to plan and the possibility of reducing the project time with minimal increase in costs. Based on Figure 1, 11 work paths are shown in the following Table 2:

Table 2. Renovation Project Pathways

Paths	Duration
A-B-C-D-E-F-G-H-I-J-M-N-U-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 31 + 5 + 15 + 6 + 4 + 1 = 194
A-B-C-D-E-F-G-H-I-J-M-O-P-U-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 31 + 5 + 15 + 9 + 8 + 4 + 1 = 205
A-B-C-D-E-F-G-H-I-J-M-O-P-S-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 31 + 5 + 15 + 9 + 8 + 8 + 1 = 209
A-B-C-D-E-F-G-H-I-J-M-O-P-T-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 31 + 5 + 15 + 9 + 8 + 4 + 1 = 205
A-B-C-D-E-F-G-H-I-J-M-O-Q-R-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 31 + 5 + 15 + 9 + 4 + 4 + 1 = 201
A-B-C-D-E-F-G-H-K-M-N-U-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 5 + 15 + 6 + 4 + 1 = 163
A-B-C-D-E-F-G-H-K-M-O-P-U-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 5 + 15 + 9 + 8 + 4 + 1 = 174
A-B-C-D-E-F-G-H-K-M-O-P-S-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 5 + 15 + 9 + 8 + 8 + 1 = 178
A-B-C-D-E-F-G-H-K-M-O-P-T-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 5 + 15 + 9 + 8 + 4 + 1 = 174
A-B-C-D-E-F-G-H-K-M-O-Q-R-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 5 + 15 + 9 + 4 + 4 + 1 = 170
A-B-C-D-E-F-G-H-K-L-V	1 + 14 + 3 + 27 + 13 + 51 + 8 + 15 + 5 + 14 + 1 = 152

In order to obtain the longest path, namely A-B-C-D-E-F-G-H-I-J-M-O-P-S-V with an estimated duration of project completion for 209 days. From Figure 1 using the CPM method the critical paths are shown in Table 3 below:

Table 3. Critical Paths to the Renovation Project

Activity	Job Description	ES	EF	LS	LF	LS-ES	LF-EF	Critical
A	-	0	1	0	1	0	0	Yes
B	A	1	15	1	15	0	0	Yes
C	B	15	18	15	18	0	0	Yes
D	C	18	45	18	45	0	0	Yes
E	D	45	58	45	58	0	0	Yes
F	E	58	109	58	109	0	0	Yes
G	F	109	117	109	117	0	0	Yes
H	G	117	132	117	132	0	0	Yes
I	H	132	163	132	163	0	0	Yes
J	I	163	168	163	168	0	0	Yes
K	H	132	137	163	168	31	31	No
L	K	137	151	194	208	57	57	No
M	J,K	168	183	168	183	0	0	Yes
N	M	183	189	198	204	15	15	No
O	M	183	192	183	192	0	0	Yea
P	O	192	200	192	200	0	0	Yes
Q	O	192	196	200	204	8	8	No
R	Q	196	200	204	208	8	8	No
S	P	200	208	200	208	0	0	Yes
T	P	200	204	204	208	4	4	No
U	N,P	200	204	204	208	4	4	No
V	L,R,S,T,U	208	209	208	209	0	0	Yes

After knowing the critical path using the PERT method, we can determine the average, variance, and standard deviation to find out the probability:

Table 4. Time Duration Data

Activity	t_o	t_p	t_m	Mean	Variance
A	0.5	1	1.2	0.9	0.013611
B	13	14	15	14	0.111111
C	2	3	5	3.333333	0.25
D	25	27	28	26.66667	0.25
E	12	13	15	13.33333	0.25
F	49	51	53	51	0.444444
G	7	8	9	8	0.111111
H	14	15	17	15.33333	0.25
I	30	31	33	31.33333	0.25
J	4	5	7	5.333333	0.25
K	4	5	6	5	0.111111
L	11	14	17	14	1
M	14	15	16	15	0.111111
N	5	6	7	6	0.111111
O	7	9	13	9.666667	1
P	7	8	10	8.333333	0.25
Q	3	4	5	4	0.111111
R	3	4	6	4.333333	0.25
S	7	8	9	8	0.111111
T	3	4	6	4.333333	0.25
U	3	4	5	4	0.111111
V	0.5	1	1.3	0.933333	0.017778

Because the critical path is A-B-C-D-E-F-G-H-I-J-M-O-P-S-V, we get variance (s^2) of 3.670278 and standard deviation (s) of 1.915797.

$$P\left(Z \leq \frac{213 - 211.167}{1.915797}\right)$$
$$P(Z \leq 0.95) = 0.8289$$

Based on the normal distribution table, P (Z≤0.95) = 0.8289 = 82%. So the probability of construction can be completed in less than 213 days is 82%.

The Crashing Program method is used to determine the acceleration of project time by adding costs, by determining the normal and crash (Δt), difference between normal and crash costs (Δc) and Slope (r), as in Table 5:

Table 5. Normal & Crash Time Data and Normal & Crash Cost

Aktivity	Normal Time	Normal Cost	Crash Time	Crash Cost	Δt	Δc	r
A	1	261,360	0.5	295,300	0.5	33,940	67,880
B	14	5,707,250	13	5,800,520	1	93,270	93,270
C	3	1,519,200	2	1,536,444	1	17,244	17,244
D	27	10,772,085	25	11,546,070	2	773,985	386,993
E	13	5,751,338	12	5,966,188	1	214,851	214,851
F	51	14,496,900	49	15,026,970	2	530,070	265,035
G	8	5,433,513	7	5,559,944	1	126,431	126,431
H	15	10,454,750	14	10,961,229	1	506,479	506,479
I	31	9,390,571	30	9,424,641	1	34,070	34,070
J	5	3,005,760	4	3,150,480	1	144,720	144,720
K	5	1,006,847	4	1,123,484	1	116,637	116,637
L	14	3,121,292	11	3,243,215	3	121,923	40,641
M	15	29,316,571	14	29,496,419	1	179,849	179,849
N	6	2,101,066	5	2,499,820	1	398,754	398,754
O	9	10,864,520	7	11,019,410	2	154,890	77,445
P	8	8,025,755	7	8,057,289	1	31,534	31,534
Q	4	1,908,000	3	1,952,400	1	44,400	44,400
R	4	5,477,920	3	5,755,650	1	277,730	277,730
S	8	1,801,144	7	1,924,824	1	123,680	123,680
T	4	5,170,000	3	5,197,662	1	27,662	27,662
U	4	1,905,000	3	1,932,000	1	27,000	27,000
V	1	1,051,320	0.5	1,093,320	0.5	42,000	84,000

After calculating using the MAPLE application, an additional cost of IDR 3,007,013 is obtained and construction can be accelerated to 192 days on the A-B-C-D-E-F-G-H-I-J-M-O-P-S-V.

3.4 Use of triangular fuzzy numbers

From the initial data after using the triangle fuzzy numbers, new data are obtained, shown in Table 6.

Table 6. New research object data

Activity	Job Description	Time	Cost (IDR)
A	-	0.9	261,353
B	A	14.0	5,707,267
C	B	3.3	1,519,200
D	C	26.7	10,772,062
E	D	13.3	5,751,346
F	E	51.0	14,496,883
G	F	8.0	5,433,521
H	G	15.3	10,454,750
I	H	31.3	9,390,557
J	I	5.3	3,005,753
K	H	5.0	1,006,849
L	K	14.0	3,121,264
M	J,K	15.0	29,316,557
N	M	6.0	2,101,055
O	M	9.7	10,864,540
P	O	8.3	8,025,752
Q	O	4.0	1,908,000
R	Q	4.3	5,477,923
S	P	8.0	1,801,148
T	P	4.3	5,173,333
U	N,P	4.0	1,905,000
V	L,R,S,T,U	0.9	1,051,340

Based on Table 6, we get the same network as Figure 1, so we get 11 work paths shown in Table 7.

Table 7. Pathway of Renovation Projects

Path	Duration (Day)
A-B-C-D-E-F-G-H-I-J-M-N-U-V	0.9+14+3.3+26.7+13.3+51+8+15.3+31.3+5.3+15+6+4+0.9=195
A-B-C-D-E-F-G-H-I-J-M-O-P-U-V	0.9+14+3.3+26.7+13.3+51+8+15.3+31.3+5.3+15+9.7+8.3+4+0.9=207
A-B-C-D-E-F-G-H-I-J-M-O-P-S-V	0.9+14+3.3+26.7+13.3+51+8+15.3+31.3+5.3+15+9.7+8.3+8+0.9=211
A-B-C-D-E-F-G-H-I-J-M-O-P-T-V	0.9+14+3.3+26.7+13.3+51+8+15.3+31.3+5.3+15+9.7++8.3+4.3+0.9= 207.3
A-B-C-D-E-F-G-H-I-J-M-O-Q-R-V	0.9+14+3.3+26.7+13.3+51+8+15.3+31.3+5.3+15+9.7+4+4.3+0.9=203
A-B-C-D-E-F-G-H-K-M-N-U-V	0.9+14+3.3+26.7+13.3+51+8+15.3+5+15+6+4+0.9=163.4
A-B-C-D-E-F-G-H-K-M-O-P-U-V	0.9+14+3.3+26.7+13.3+51+8+15.3+5+15+9.7+8.3+4+0.9=175.4
A-B-C-D-E-F-G-H-K-M-O-P-S-V	0.9+14+3.3+26.7+13.3+51+8+15.3+5+15+9.7+8.3+8+0.9=179.4
A-B-C-D-E-F-G-H-K-M-O-P-T-V	0.9+14+3.3+26.7+13.3+51+8+15.3+5+15+9.7+8.3+4.3+0.9=175.7
A-B-C-D-E-F-G-H-K-M-O-Q-R-V	0.9+14+3.3+26.7+13.3+51+8+15.3+5+15+9.7+4+4.3+0.9=171.4

The use of CPM methods from the data results of the application of Fuzzy triangle numbers. Based on the network from Figure 1, the critical path obtained is shown in Table 8.

Table 8. Results of Forward and Backward Calculations and Critical Paths

Activity	Job Description	ES	EF	LS	LF	LS-ES	LF-EF	Critical
A	-	0.0	0.9	0.0	0.9	0.0	0.0	Yes
B	A	0.9	14.9	0.9	14.9	0.0	0.0	Yes
C	B	14.9	18.2	14.9	18.2	0.0	0.0	Yes
D	C	18.2	44.9	18.2	44.9	0.0	0.0	Yes
E	D	44.9	58.2	44.9	58.2	0.0	0.0	Yes
F	E	58.2	109.2	58.2	109.2	0.0	0.0	Yes
G	F	109.2	117.2	109.2	117.2	0.0	0.0	Yes
H	G	117.2	132.5	117.2	132.5	0.0	0.0	Yes

I	H	132.5	163.8	132.5	163.8	0.0	0.0	Yes
J	I	163.8	169.1	163.8	169.1	0.0	0.0	Yes
K	H	132.5	137.5	164.1	169.1	31.6	31.6	No
L	K	137.5	151.5	196.1	210.1	58.6	58.6	No
M	J,K	169.1	184.1	169.1	184.1	0.0	0.0	Yes
N	M	184.1	190.1	200.1	206.1	16.0	16.0	No
O	M	184.1	193.8	184.1	193.8	0.0	0.0	Yes
P	O	193.8	202.1	193.8	202.1	0.0	0.0	Yes
Q	O	193.8	197.8	201.8	205.8	8.0	8.0	No
R	Q	197.8	202.1	205.8	210.1	8.0	8.0	No
S	P	202.1	210.1	202.1	210.1	0.0	0.0	Yes
T	P	202.1	206.4	205.8	210.1	3.7	3.7	No
U	N,P	202.1	206.1	206.1	210.1	4.0	4.0	No
V	L,R,S,T,U	210.1	211.0	210.1	211.0	0.0	0.0	Yes

The critical paths are: A-B-C-D-E-F-G-H-I-J-M-O-P-S-V with an estimated duration of completion of the project for 211 days.

The use of PERT method from the data from the application of the triangle fuzzy numbers.

Table 9. Job Time Data

Activity	t_o	t_p	t_m	Mean	Variance
A	0.6	0.9	1.2	0.911111	0.011142
B	13.0	14.0	15.0	14	0.111111
C	2.0	3.3	4.7	3.333333	0.197531
D	25.3	26.7	28.0	26.66667	0.197531
E	11.7	13.3	14.7	13.22222	0.25
F	49.0	51.0	52.7	50.88889	0.373457
G	7.0	8.0	9.0	8	0.111111
H	14.0	15.3	16.7	15.33333	0.197531
I	30.0	31.3	32.7	31.33333	0.197531
J	3.7	5.3	6.7	5.222222	0.25
K	4.0	5.0	6.0	5	0.111111
L	11.7	14.0	16.3	14	0.604938
M	13.7	15.0	16.0	14.88889	0.151235
N	5.0	6.0	7.0	6	0.111111
O	7.3	9.7	12.0	9.666667	0.604938
P	6.7	8.3	9.7	8.222222	0.25
Q	3.0	4.0	5.0	4	0.111111
R	3.0	4.3	5.7	4.333333	0.197531
S	6.7	8.0	9.0	7.888889	0.151235
T	2.7	4.3	5.7	4.222222	0.25
U	3.0	4.0	5.0	4	0.111111
V	0.6	0.9	1.3	0.944444	0.011142

Because the critical path is A-B-C-D-E-F-G-H-I-J-M-O-P-S-V, obtained variance (s^2) of 3.065493827 and standard deviation (s) of 1.75085517024124. To calculate the probability equation is used $P\left(Z \leq \frac{213-210.522}{1.75085517024124}\right)$ so that $P(Z \leq 1.41) = 0.9207$. Based on the normal distribution table, P (Z≤1.41) = 0.9207 = 92%. So the probability of construction can be completed in less than 213 days is 92%.

The use of the Crashing Program method from the results of the application of the triangle fuzzy number.

Table 10. Normal and Crash Time Data and Normal and Crash Costs

Activity	Normal Time	Normal Cost	Crash Time	Crash Cast	Δt	Δc	r
A	0.9	261,353	0.6	295,300	0.3	33,947	113,156
B	14.0	5,707,267	13.0	5,800,540	1.0	93,273	93,273
C	3.3	1,519,200	2.0	1,536,448	1.3	17,248	12,936
D	26.7	10,772,062	25.3	11,546,057	1.3	773,995	580,496
E	13.3	5,751,346	11.7	5,966,163	1.7	214,817	128,890
F	51.0	14,496,883	49.0	15,026,970	2.0	530,087	265,043
G	8.0	5,433,521	7.0	5,559,931	1.0	126,410	126,410
H	15.3	10,454,750	14.0	10,961,243	1.3	506,493	379,870
I	31.3	9,390,557	30.0	9,424,647	1.3	34,090	25,568
J	5.3	3,005,753	3.7	3,150,460	1.7	144,707	86,824
K	5.0	1,006,849	4.0	1,123,461	1.0	116,612	116,612
L	14.0	3,121,264	11.7	3,243,238	2.3	121,974	52,275
M	15.0	29,316,557	13.7	29,496,440	1.3	179,883	134,912
N	6.0	2,101,055	5.0	2,499,840	1.0	398,785	398,785
O	9.7	10,864,540	7.3	11,019,437	2.3	154,897	66,384
P	8.3	8,025,752	6.7	8,057,263	1.7	31,511	18,907
Q	4.0	1,908,000	3.0	1,952,500	1.0	44,500	44,500
R	4.3	5,477,923	3.0	5,755,650	1.3	277,727	208,295
S	8.0	1,801,148	6.7	1,924,841	1.3	123,693	92,770
T	4.3	5,173,333	2.7	5,197,654	1.7	24,321	14,592
U	4.0	1,905,000	3.0	1,933,000	1.0	28,000	28,000
V	0.9	1,051,340	0.6	1,093,340	0.3	42,000	140,000

After calculating using the MAPLE application, an additional fee of IDR 2,951,115 is obtained and construction can be accelerated to 191.3 days on the A-B-C-D-E-F-G-H-I-J-M-O-P-S-V.

4 Conclusion

Based on the results of data analysis based on estimated time and probability using CPM and PERT, the calculation of the acceleration of estimated time and additional costs using the Crashing Program Method, obtained:

1. By using the PERT Method, an estimated renovation project time is 209 days and the probability of renovation can be completed in 213 days is 82%.
2. By using the PERT Method with Fuzzy Logic, the estimated renovation project time is 211 days and the probability of renovation being

completed in less than 213 days is 92%.

3. By using the Crashing Program Method, renovation projects can be accelerated to 192 days at an additional cost of IDR 3,007,013.
4. By using the Crashing Program Method with Fuzzy Logic, the renovation project can be accelerated to 191.3 days with an additional cost of IDR 2,951,115.

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